8 Boiling in Micro-Structures and Porous Media

Abstract An experimental investigation was conducted to visually observe the boiling behavior in a 3D porous structure made of staggered glass beads, especially the bubble dynamics and pore-scale liquid flow around bubbles associated with the heat and mass transport at the bubble interface. The experiments show that the dynamic bubble behavior was significantly affected by the bead-packed structure, and several unique boiling phenomena caused by special pore geometry were observed and discussed. Intensive wetting of the liquid replenishment protected heated surface from full dryout. The bubble shape and primary bubble interface were described by using a force balance on the bubble. An introductory model was proposed to perform a theoretical analysis and explore the dryout process inside the pore structure. The theoretical results were compared with experimental data, and the present model provided a good explanation of the fundamental mechanisms and predicted the important influences of the bead-packed structure on dryout behavior.

Keywords interface, bubble dynamics, boiling, bead-packed structure, replenishment, dryout

Many efforts have been devoted to studying phase-change heat transfer in the porous structure with a horizontal heated surface in the past owing to their important technological applications [1]. In this work, an experimental investigation of boiling heat transfer in a porous structure, as shown in Fig. 8.1, was performed, and the efforts on this topic were driven by the development of the porous-wicked evaporator for capillary pumped loops (CPL) system. CPL is a high-performance heat transport device that is widely used for cooling of modern electronic devices [2, 3] as well as for the thermal management of advanced aerospace vehicles [4, 5]. As the key component of CPL system, the porous-wicked evaporator represents the heart of a CPL system and correspondingly determines the available capillary pumping head for heat transport of the overall loop. The contribution of interfacial effects on boiling heat transfer is extremely distinct in porous media, where unique phenomena, or problems, may arise because the dynamic behavior of the bubble interface is significantly affected by the porous structure during boiling [6].
8.1 Experimental Observations

8.1.1 Test Apparatus

The experimental apparatus shown in Figs. 8.1 and 8.2 were used for visual observations and test measurements of boiling phenomena occurring in various porous structures and/or porous media. Normally, glass beads having different sizes are employed as porous materials or simulate porous structures. In the conducted experiments transparent test sections were packed with glass beads, having an average particle diameter of $0.5 - 7$ mm. The phase-change behavior within the bead-packed structure could be observed through the front glass-pane. The bead-packed structure saturated with working fluid was heated from the vessel bottom by a heating assembly consisting of a labyrinth-type foil heater mounted on the bottom and a DC power supply. Wang et al. [6 – 8] described the experimental devices and test procedures in detail. Experiments were performed for different conditions, including various pore structures, fluids, and thermal boundary conditions.

![Schematic diagram of the experimental apparatus](image)

The planform of the porous structure adjacent to the heated surface is shown in Fig. 8.3. For the purpose of studying the bubble behavior in the porous structure adjacent to the heated surface, the pore space adjacent to the heated surface is